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## Prehistoric animal use on the Great Hungarian Plain: A synthesis of isotope and residue analyses from the Neolithic and Copper Age

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## ABSTRACT

The archaeological record of Eastern Hungary indicates that settlement patterns, subsistence strategies, ceramic style, trade patterns and mortuary customs changed from the Late Neolithic to the Copper Age (5000–2700 cal BC). Despite a rich archaeological tradition, questions remain regarding the management and use of domesticated animals and the role animal husbandry played in social change during this transition. Some researchers have hypothesized that these changes reflect a shift towards an economy that intensified its focus on primary and perhaps secondary animal products. Here we synthesize isotope data from human and animal remains and residue analysis from pottery sherds from Neolithic and Copper Age assemblages. Results indicate that the consumption and use of animal protein and fat was relatively high for both periods, with an increase in animal fats in ceramic vessels during the Middle Copper Age; however, milk products do not appear to have played an important dietary role. We conclude that livestock management remained small-scale during the Neolithic and Copper Age and that dairy use was minimal. It is proposed that the cultural changes that occurred at this time were associated with the emergence of smaller, independent farmsteads and perhaps the innovative use of secondary products like manure.

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## Introduction

Understanding how populations use animals and how their use patterns change helps us to understand larger social shifts, as social organization and subsistence patterns are linked and changes in one aspect will result in changes in the other. In this article, we synthesize our results from isotope and residue analysis within the context of the rich archaeological tradition in Hungary and provide a holistic, integrated interpretation of animal use and culture change in the Neolithic and Copper Age of the Great Hungarian Plain.

To complete this synthesis, we evaluate previously published faunal data as well as new evidence from isotope and residue analysis for domesticated animal use during the Neolithic and Copper Age periods of Eastern Hungary. Specifically, we address the transition that occurred from the Late Neolithic to the Copper Age (4500 cal BC), when several aspects of material culture changed. Large, multilayer tell sites were gradually replaced by smaller, more dispersed hamlets. Three distinct ceramic styles of the Late Neolithic period (Tisza–Herpály–Csőszhalom) gave way to the more homogenous Tiszapolgár style (Parkinson, 1999). Regional

trade networks were favoured over the long-distance exchange systems of the past and the production of metals became an important part of the economy. Finally, for the first time the dead were buried in communal cemeteries, although the previous intersite burial tradition was not abandoned. Various models have been proposed to explain these changes including migration (Gimbutas, 1982), climate change (Bánffy, 1994; Horváth and Virág, 2003), scalar stress (Gyucha et al., 2009; Kalicz, 1988; Whittle, 1996), conflict (Chapman, 1999), a subsistence shift (Bökönyi, 1988a), and multifactor models that incorporate environmental degradation, technological innovation and social reorganization (Chapman, 1990; Gyucha et al., 2009; Parkinson et al., 2010; Sherratt, 1984). In this article, we examine these models in light of new data from isotopic and residue analyses.

*Animal product use during the Neolithic and Copper Age on the Great Hungarian Plain*

The Great Hungarian Plain, or *Nagy Alföld*, is a flat, poorly drained landscape composed of alluvial and aeolian sediments that makes up the eastern portion of the Middle Danubian Basin (Fig. 1). It is one of the largest alluvial plains in Europe, encompassing an area of approximately 100,000 km<sup>2</sup>, with roughly 60% falling within the present Hungarian border (Gábris and Nádor, 2007). Reconstructed vegetation patterns for the Neolithic and Copper Age time

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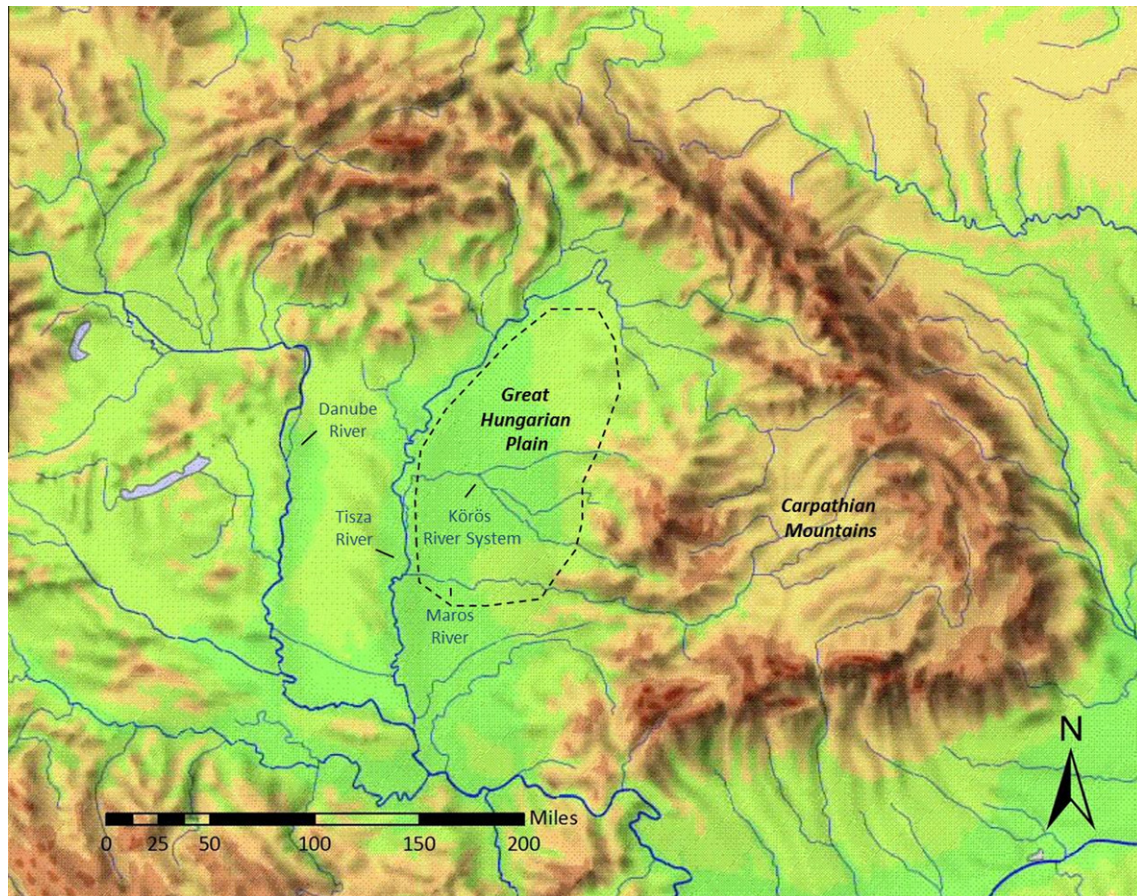


Fig. 1. Map of the Carpathian Basin. Adapted from topographic base map created by László (1996).

periods characterize the flora as steppe, forest-steppe with pockets of mixed deciduous forest, and the climate as primarily arid and continental (Gardner, 2002; Nagy-Bodor et al., 2000; Willis, 2007).

The cattle, sheep, goats and pigs used by the early farming communities of the Great Hungarian Plain were domesticated in the Near East and brought to Hungary as part of the Starčevo–Körös–Criș cultural complex (Bartosiewicz, 2005; Zvelebil, 2004). The presence and use of these livestock have been largely studied through faunal assemblages with major contributions from the work of Sándor Bökönyi and László Bartosiewicz. Throughout the 1970s, 1980s and 1990s, Bökönyi's analysis of animal remains from sites in Hungary, the Balkan Peninsula and the Near East made a significant contribution to research on the history of animal husbandry and early agricultural practices in Eastern and Central Europe (e.g., Bökönyi, 1971, 1985, 1986, 1987, 1988a,b, 1993), a tradition that has been continued by Bartosiewicz (e.g., 1999, 2003, 2005, 2006, 2007; Bartosiewicz et al., 1997).

In a recent evaluation of faunal assemblages from Neolithic and Copper Age sites from Eastern Hungary, Bartosiewicz (2005) showed that ovicaprids were the most common domesticated species during the Early Neolithic (6000–5500 cal BC), while the numbers of cattle and domesticated pigs increased during the Middle Neolithic (5500–5000 cal BC; Tables 1 and 2). During both periods, 89% of the large mammal faunal remains recovered were from domesticated species and only 11% were from wild mammals (primarily aurochs, wild boar, and deer). In the Late Neolithic (5000–4500 cal BC), wild mammal remains increased to 42%, and only 58% of all large mammal remains recovered were domesticated species. There were fewer ovicaprids than expected in the Late Neolithic faunal assemblages (Bartosiewicz, 2005, Table 1).

Table 1

Summary of faunal data from the Great Hungarian Plain, illustrating temporal patterns of animal resource exploitation (wild vs. domesticated species). Adapted from data presented in Nicodemus (2003:50–58, 94), and also Nicodemus and Kovács (forthcoming).

| Time period       | Culture                | NISP               | Wild (%) | Domestic (%) |
|-------------------|------------------------|--------------------|----------|--------------|
| Early Neolithic   | Körös                  | 26119 <sup>a</sup> | 33       | 67           |
| Middle Neolithic  | AVK                    | 4065               | 16       | 84           |
| Late Neolithic    | Herpaly/<br>Csoszhalom | 5731               | 74       | 26           |
| Late Neolithic    | Tisza                  | 2115               | 44       | 56           |
| Early Copper Age  | Tiszapolgar            | 3106               | 12       | 88           |
| Middle Copper Age | Bodrogkeresztur        | 50,592             | 12       | 88           |
| Late Copper Age   | Baden/Pecel            | 1969               | 12       | 88           |

<sup>a</sup> NISP for 3 sites not included, since  $n < 100$  and were excluded from the original table.

There are only a few faunal assemblages from Early Copper Age sites on the Plain, but while Lengyel groups to the west (in Transdanubia) continued the animal exploitation pattern observed during the Late Neolithic, at two small Tiszapolgar sites (Vésztő-Bikeri and Körösladány-Bikeri), domesticated species accounted for over 96% of all the mammal faunal remains. Roughly equal numbers of cattle (31%), ovicaprid (40–41%), and pig (28–29%) remains were recovered (Nicodemus and Kovács, forthcoming). During the Middle Copper Age, while wild mammal remains are still rare, 74% or more of the domesticated faunal remains recovered are from cattle (Bökönyi, 1959; Vörös, 1987). This increase could be due to the greater value of cattle as a food source, a traction animal, or a



**Table 2**

Summary of faunal data from the Great Hungarian Plain, illustrating temporal patterns of animal resource exploitation (for separate domesticated species). Adapted from data presented in Nicodemus (2003:50–58, 94), and also Nicodemus and Kovács (forthcoming).

| Time period       | Culture            | NISP               | Cattle (%) | Ovicaprids (%) | Pig (%) |
|-------------------|--------------------|--------------------|------------|----------------|---------|
| Early Neolithic   | Koros              | 26119 <sup>a</sup> | 33         | 64             | 3       |
| Middle Neolithic  | AVK                | 4065               | 54         | 24             | 22      |
| Late Neolithic    | Herpaly/Csoszhalom | 5731               | 64         | 10             | 26      |
| Late Neolithic    | Tisza              | 2115               | 78         | 6              | 15      |
| Early Copper Age  | Tiszapolgar        | 6787               | 47         | 31             | 21      |
| Middle Copper Age | Bodrogkeresztur    | 50,592             | 83         | 6              | 11      |
| Late Copper Age   | Baden/Pecel        | 1969               | 55         | 33             | 12      |

<sup>a</sup> NISP for 3 sites not included, since  $n < 100$  and were excluded from the original table.

status symbol (or some combination, e.g. Twiss, 2008). By the Late Copper Age, settlement was expanded into new environments (Parkinson, 2006) including upland areas. Cattle were clearly important, as they are commonly found laid out in burials (Whittle, 1996, 122–131). These burials often feature a pair of cattle, or humans and cattle buried together. Researchers on faunal pathologies have suggested that these cattle burials are pairs of oxen used for traction (Bartosiewicz, et al., 1997; Fabiš, 2005).

One of the most notable changes from the Late Neolithic to the Copper Age is a shift in the settlement pattern from large nucleated tell sites to more dispersed and ephemeral flat sites (Kalicz, 1970; Kalicz and Makkay, 1977; Kalicz and Raczky, 1987; Makkay, 1982; Parkinson, 1999, 109; Raczky, 1989; Renfrew, 1994, 159–160). In 1988, Sándor Bökönyi suggested that the shift in settlement strategies associated with the Neolithic–Copper Age transition on the Great Hungarian Plain was linked to an increase in cattle husbandry, which he identified as the local manifestation of the secondary products revolution. He reasoned that larger cattle herds would require more grazing land, so Early Copper Age groups were forced to utilize a more dispersed settlement strategy than the tell-centred Late Neolithic farmers (Bökönyi, 1988a), and this idea continues to be cited (e.g., Bánffy, 1994, 1995; Molnár and Sümegei, 2007). One aspect of animal utilization often overlooked is the use of secondary products. Aside from being good sources of meat on demand (walking larders – Clutton-Brock, 1989), secondary products like wool, milk, manure and traction diversify the ways in which domesticated animals can be used. Currently, the evidence for secondary product use is variable in southeastern Europe and indicates several points of development instead of a necessarily-unified package, as originally proposed by Andrew Sherratt in the 1980s (Sherratt, 1981, 1983).

## Research questions

Previous archaeological and zooarchaeological research in this region highlights two questions related to domesticated animal use during the Neolithic and Copper Age: (1) did herd mobility increase during the Copper Age (related to changes in settlement patterns), and (2) did domesticated animal products (meat and dairy) increase in importance (as reflected in the increased reliance on domesticated animals vs. wild species)? Many researchers have hypothesized that these changes at the start of the Copper Age in Eastern Hungary reflect a shift towards an economy that intensified its focus on primary and perhaps secondary animal products. A deeper understanding of animal husbandry in this region will clarify the way that livestock was actually used which, in turn, will contribute to our understanding of the processes that led to culture change during the post-Neolithic in southeastern Europe.

Our ability to answer these important subsistence-related questions has been hampered by a lack of comparable faunal assemblages from Copper Age sites. Previous research on the Great Hungarian Plain has focused on the first farmers of the Early

Neolithic (e.g., Whittle, 2007) and the tell builders of the Late Neolithic settlements (e.g., Raczky, 1987). It is not until recently that Copper Age sites have been systematically excavated (Gyucha, 2009; Gyucha et al., 2004, 2006, 2007, 2009, 2011; Parkinson, 2006; Parkinson et al., 2002, 2004a, 2004b, 2010; Yerkes et al., 2007, 2009). Despite this growing body of work on Copper Age sites, for comparison purposes the faunal data remain disproportionately under represented.

While the faunal data is currently limited, approaches within the field of archaeological chemistry provide alternative ways to address subsistence related questions. In this study we applied two such methods to Neolithic and Copper Age archaeological assemblages: (1) the analysis of isotope abundances in human skeletal remains, and (2) the identification of animal fat residues from pottery sherds. These methods are becoming increasingly useful tools in the analysis of archaeological data, but are rarely interpreted together to understand the role of animal husbandry in the past. They also focus on different data sets – human remains and pottery – and therefore circumvent the need for comparable faunal assemblages.

In the following section, we provide the theoretical basis for the application of each of these approaches. First, the issue of livestock management and use is addressed in the context of isotopic approaches to mobility and dietary reconstructions. This is followed by a discussion of secondary product exploitation in Eastern Hungary, with an emphasis on organic residue analysis and the identification of dairy products.

## Livestock management

As previously mentioned, some researchers have hypothesized that the ephemeral nature of Copper Age settlements in Eastern Hungary is indicative of a more mobile lifestyle focused on the maintenance of large animal herds (Bánffy, 1994, 1995; Bökönyi, 1988a; Molnár and Sümegei, 2007). It has been suggested that changes in livestock management (i.e., the expansion of herd sizes and geographic range) may have been associated with the shift from using domesticated livestock primarily for their meat to their use for secondary products (Bökönyi, 1988a; Sherratt, 1981, 1983). According to this model, domestic herd sizes were increased to more effectively produce secondary products and these animals were herded to unoccupied upland pasture during the summer to avoid putting strain on local economies. In historic times, the Great Hungarian Plain served as lowland, winter pasture by transhumant herders who managed hundreds of thousands of sheep and goats (see Bartosiewicz, 1999). Herds were moved to highland pasture in the Southern and Eastern Carpathians during the summer. While historic scale animal herding strategies seem unlikely for these early tribal societies (see Parkinson, 2002a,b for a discussion of tribal social organization in Eastern Hungary), it remains to be tested whether animal husbandry was intensified during the Copper Age as part of the suite of cultural changes that have been observed.

The analysis of stable and radiogenic isotopes from human skeletal material has been used in archaeological research for several decades to reconstruct prehistoric dietary and mobility patterns, including shifts from sedentary to more mobile settlement and subsistence strategies (for a recent overview of literature see [Schwarcz et al., 2010](#)). Briefly, isotopes of various elements are incorporated into the organic and inorganic portion of the skeletal system as these tissues are formed and, if preserved, the chemical signature can reflect varying aspects of human and animal behaviour. A variety of isotopes have useful applications in archaeological research (e.g., strontium, oxygen, carbon, nitrogen, sulphur, hydrogen). For example, the radiogenic isotope of strontium ( $^{87}\text{Sr}/^{86}\text{Sr}$ ) is incorporated into the mineral phase of bone and teeth and records geological characteristics of the environment where an individual was consuming resources (see [Bentley, 2006](#); [Price et al., 2002](#)). Conversely, in the organic phase of bone, the isotopes of carbon ( $\delta^{13}\text{C}$ ) and nitrogen ( $\delta^{15}\text{N}$ ) vary depending on the type and quantity of plants and animals in the diet ([Ambrose, 1990](#); [DeNiro and Epstein, 1978, 1981](#); [Hedges and Reynard, 2007](#); [Schoeninger and DeNiro, 1984](#); [Tieszen, 1991](#); [van der Merwe, 1982](#)).

Additionally, isotope analysis of archaeological animal remains is increasingly used to shed light on livestock management patterns in the prehistoric record. Sequential sampling of  $^{87}\text{Sr}/^{86}\text{Sr}$  and  $\delta^{18}\text{O}$  values from the molars of livestock has been used to study seasonal herd mobility and animal exchange patterns (i.e., [Balasse et al., 2002](#); [Bentley and Knipper, 2005](#); [Bocherens et al., 2001](#); [Mashkour, 2003](#); [Viner et al., 2010](#)). Studies of  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values from animal bone collagen have been used to characterize grazing and foddering strategies (i.e., [Atahan et al., 2011](#); [Oelze et al., 2011](#); [Towers et al., 2011](#)).

Isotope applications to archaeological questions in Hungary are relatively sparse with the few published studies focusing on dietary reconstruction (using carbon and nitrogen isotope analysis) during the Early and Middle Neolithic time periods ([Cramp, 2004](#); [Pearson and Hedges, 2007](#); [Whittle et al., 2002](#)). One of the authors in this study, analyzed a small sample of humans and animals dating to the Late Neolithic and Copper Age time periods from the Great Hungarian Plain to explore the utility of strontium isotopes to address questions of human and animal movement in prehistoric Hungary ([Giblin, 2004, 2007, 2009](#)). Strontium isotope values from the Copper Age samples were more variable than the values in the Late Neolithic samples and [Giblin \(2009\)](#) hypothesized that this increased variance was related to the consumption of food sources such as meat and dairy that were obtained from livestock that were grazed over larger areas. Variability in “background”  $^{87}\text{Sr}/^{86}\text{Sr}$  isotope ratios exists throughout the Carpathians, particularly in the surrounding mountain ranges, due to differences in the age and mineral source material of the geological formations ([Seghedi et al., 2004](#)). If herders became more mobile in the Copper Age, and utilized greater areas, including the flanks of the Carpathian Mountains, this variability would be recorded in animal and human dental enamel because strontium is obtained from all dietary sources and is incorporated into the skeleton as these tissues are formed.

To evaluate these previous assumptions and preliminary strontium isotope results that suggested that a mobile agropastoral economy developed during the Hungarian Copper Age, small skeletal samples were taken from humans and animals from throughout the Great Hungarian Plain that span the Late Neolithic – Middle Copper Age time sequence ([Giblin, 2011](#)). These samples were analyzed for their isotopic composition (strontium, carbon and nitrogen isotopes) to measure residence, herd management and dietary patterns over time. Specifically, two hypotheses were addressed: (1) mobility increased from the Neolithic to the Copper Age; and (2) diet became more focused on domesticated plants and animals. Stable strontium isotope ratios ( $^{87}\text{Sr}/^{86}\text{Sr}$ ) in human

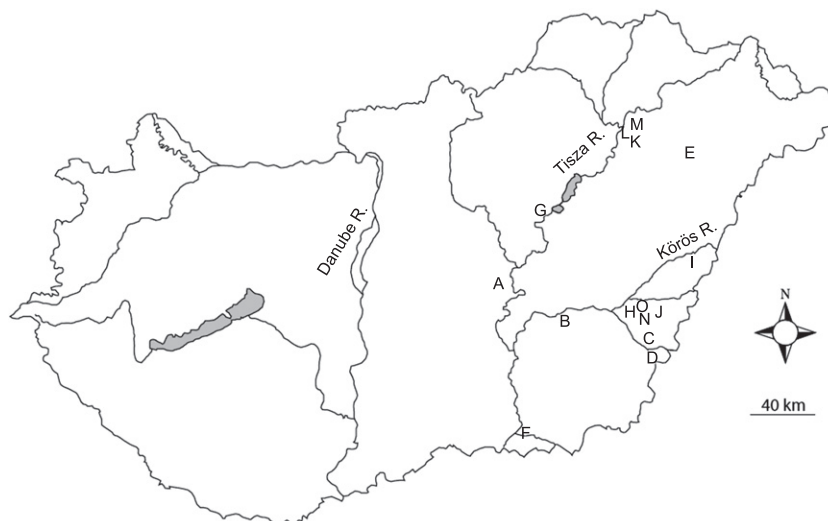
and animal dental enamel were used to test the first hypothesis, and the abundance of stable carbon ( $\delta^{13}\text{C}$ ) and nitrogen ( $\delta^{15}\text{N}$ ) isotopes in human and animal bone were used to test the second. The results of these analyses will be discussed in the *Methods and Results* and *Discussion* sections.

### Secondary product exploitation

In the early 1980's, Andrew Sherratt outlined his 'Secondary Products Revolution' hypothesis for the Old World which proposed that domesticated livestock were originally used for meat production, and it was not until the post-Neolithic (Chalcolithic and Bronze Age) that these domesticates were utilized for their secondary products (such as milk, wool, and traction) ([Sherratt, 1981, 1983](#)). These seminal papers sparked a lively debate over the origins, spread and importance of secondary products in Europe and the Near East, and several lines of evidence have been used to examine the issue, including faunal remains (bone size, bone morphology, population mortality curves), iconography, artifacts, chemical analysis, and genetic studies ([Burger et al., 2007](#); [Chapman, 1983](#); [Craig et al., 2003, 2005](#); [Evershed et al., 2008](#); [Greenfield, 1988, 2005, 2010](#); [Marciniak, 2005](#)).

Traditionally, secondary products like wool, milk, manure, and traction have been considered together as related aspects of the 'Secondary Products Revolution' ([Sherratt, 1981, 1983](#)). In a recent review of the evidence for the appearance of secondary products in southeastern Europe, [Hoekman-Sites \(2011, 63–74\)](#) suggested that discussing the 'Secondary Products Revolution' as a group of related activities is misleading, since the various forms of animal intensification are not related chronologically or behaviourally. In southeastern Europe, dairying originated during the Early Neolithic in Hungary ([Craig et al., 2005, 2007](#)), while traction appears in Romania by the Late Neolithic period ([Mateescu, 1975](#)). Wool exploitation also began by the Late Neolithic, based on spindle whorl finds in Bulgaria ([Bailey, 2004](#)), and evidence for manuring has not been detected archaeologically until the Early Bronze Age in Greece ([Bintliff, 2005](#); [Valamoti, 2004](#); [Valamoti and Jones, 2003](#)). In addition, the innovations grouped under the 'Secondary Products Revolution' heading do not appear to be related behaviourally. The processes involved in these developments are widely variable, and these innovations did not spread across southeastern Europe in a similar manner. For example, wool use spread rapidly after its initial appearance ([Russell et al., 2004, 327–328](#)). Wool-bearing sheep may have appeared relatively late in this region, but once they were established as the dominant breed, they quickly replaced previous sheep breeds with coarser coats. Evidence for dairy use, on the other hand, appears during the Early Neolithic in eastern Hungary, but early studies do not illuminate any possible patterns of early dairy use ([Craig et al., 2003, 2007](#)).

Previous evidence for dairying was restricted largely to cattle mortality curves, which track dairying indirectly by interpreting herd culling strategies (ala [Payne, 1973](#)). However, there are several problems with using mortality curves to infer shifts in cattle utilization, including inconsistent methods of excavation and the inability to age and sex many bones found (for a more complete discussion of associated issues, see [Greenfield, 1988, 2010](#)). Early faunal analyses using mortality curves yielded a wide range of conflicting results. [Bökönyi and Greenfield](#) both examined faunal mortality curves from the Neolithic sites in the Balkans and came to very different conclusions. [Bökönyi \(1988a\)](#) suggested that an increase in cattle husbandry related to secondary products usage occurred at the end of the Neolithic based on his analysis of the fauna from Divostin, Serbia. [Greenfield \(1988\)](#), on the other hand, identified no change in cattle utilization at the end of the Neolithic based on faunal analysis from 13 sites in the Central Balkans (including Divostin). To complicate matters further, [Bogucki \(1984a, 1984b\)](#)



**Fig. 2.** Map of Hungary showing the location of the sites mentioned in the text. A: Abony 36, B: Békésszentandrás–Furugy, C: Doboz–Sarkadi–úti erdő, D: Gyula–Remete, E: Hajdúböszörmény–Ficsori-tó, F: Hódmezővásárhely–Gorzsa, G: Kisköre–Gát, H: Körösladány–Bikeri, I: Magyarhomorog, J: Okány 6, K: Polgár–Csőszhalom, L: Polgár–Piócási-dűlő, M: Tiszapolgár–Basatanya, N: Vésztő–Bikeri, and O: Vésztő–Mágor.

proposed that dairying originated at the beginning of the Neolithic based on ceramic sieve findings and flourished at the end of the Neolithic based on mortality curve data (including that gathered by Greenfield (1988).

The ‘Secondary Products Revolution’ debate was reignited by the development and application of residue analysis to detect specific animal products in ceramic sherds. Initially developed by Evershed (Evershed et al., 1997; Dudd and Evershed, 1998), Craig et al. (2003) adapted the original methodology and applied it to Neolithic ceramics in Hungary. While Craig’s work proved conclusively that dairying was practiced during the Early Neolithic, the sample size was too small ( $n = 18$ ) to say anything about the nature and extent of early dairy use. More recently, Craig et al. (2007) published residue analysis work from Ecsegfalva 23, Hungary, as part of a larger research volume for the site (Whittle, 2007). This research once again provided evidence for the presence of dairy residues in Early Neolithic ceramics. Additionally, it illustrated the key role dairy residue studies can play if integrated into larger archaeological investigations of early agricultural societies.

Although the presence of dairy residues in Early Neolithic Hungary has been shown, a greater number of sherds were examined using residue analysis so that animal use patterns could be traced through time (Hoekman-Sites, 2011). The goal of the residue analysis discussed in this article was to explore the nature and extent of all animal product use during the Late Neolithic and Copper Age periods, focusing especially on dairy products. Specifically, the hypothesis that the society-wide changes observed at the start of the Copper Age in Eastern Hungary were related to an intensification of primary and secondary animal product use was tested.

## Methods and results

### *Assessing human and animal mobility using strontium isotopes*

To test the hypothesis that humans were acquiring resources from a greater geographic range during the Copper Age both for themselves and for their domesticates, samples were taken from human dental enamel (molars) and bone from six Neolithic and Copper Age sites from the Great Hungarian Plain and added to previously collected isotope data ( $n = 125$ ). These sites include Hódmezővásárhely–Gorzsa, Kisköre–Gát, Polgár–Csőszhalom,

Tiszapolgár–Basatanya, Hajdúböszörmény–Ficsori-tó and Magyarhomorog (Fig. 2). Sequential samples of strontium isotopes from the dental enamel of livestock (cattle, sheep and goat) raised by Neolithic and Copper Age groups were also analyzed. Serial samples were taken from animal molars from three sites ( $n = 42$ ). These sites include Polgár–Piócási-dűlő, Vésztő–Bikeri and Abony 36. Tooth enamel and bone samples for strontium isotope analysis were prepared in the Archaeological Chemistry Laboratory at Arizona State University using protocol established by Knudson and Price (2007) and analyzed at the W.M. Keck Foundation Lab for Environmental Biogeochemistry at Arizona State. It was suspected that these results would document a change in the range of strontium isotope values over time. The prediction was that Late Neolithic communities would exhibit a narrow range of  $^{87}\text{Sr}/^{86}\text{Sr}$  values, while Copper Age humans and animals would have a broader range of values if herds of animals were being grazed over larger, and hence isotopically more variable, environments.

The  $^{87}\text{Sr}/^{86}\text{Sr}$  results from Neolithic and Copper Age human teeth show that there is no significant increase in variability from the Late Neolithic to the Early Copper Age as initially suspected (Fig. 3). However, the Middle Copper Age samples are statistically more variable than both the Late Neolithic and the Early Copper Age samples. The results from sequential samples of cattle and sheep/goat molars, which records a linear time sequence of one to two years, also did not show a clear change in variability over time or seasonal fluctuation between the Plain (high strontium values) and highland regions (low strontium values) (Fig. 4). These results indicate that herding strategies on the Great Hungarian Plain probably did not change substantially from the Neolithic to the Copper Age and that none of the animals were herded in upland areas of the Carpathians where sources with lower strontium isotope ratios exist.

### *Assessing human and animal diet using carbon and nitrogen isotopes*

Carbon and nitrogen isotope ratios ( $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$ ) from human bone from nine Neolithic and Copper Age sites were sampled ( $n = 97$ ) along with animal bone samples from three sites ( $n = 51$ ). These sites include Hódmezővásárhely–Gorzsa, Kisköre–Gát, Polgár–Csőszhalom, Tiszapolgár–Basatanya, Hajdúböszörmény–Ficsori-tó, Magyarhomorog, Vésztő–Mágor, Okány 6, and Vésztő–Bikeri for the human samples (Fig. 2). Animal samples came from

Polgár-Piócási-dűlő, Vésztő-Bikeri and Abony 36. Samples were prepared for isotope analysis in the David M. Yerkes and Timothy L. Johnson Memorial lab and in the Human Biology lab at The Ohio State University according to procedures described by Ambrose (1990) and analyzed at the Stable Isotope Biogeochemistry Laboratory at Ohio State. These data were collected to address the central hypothesis that dietary practices changed from the Late Neolithic to the Copper Age, with an increased emphasis on domesticated animal proteins. It was initially predicted that the resulting nitrogen isotope data from this application would exhibit more enriched isotope values in the Copper Age samples due to proposed increases in the consumption of meat and dairy from domesticated livestock. It was also predicted that carbon isotope values would be more enriched in the Copper Age human samples due to increased human consumption of the C<sub>4</sub> plant millet (or through using millet for fodder for domesticated animals) and reduced consumption of wild animals such as freshwater fish.

In general, the  $\delta^{13}\text{C}$  values from this study ( $-21\%$  to  $-19\%$ ) indicate that all of the humans in the sample consumed terrestrial plants and animals, and that millet ( $\delta^{13}\text{C}$  enriched) and freshwater fish ( $\delta^{13}\text{C}$  depleted) did not make significant contributions to the diet during the Late Neolithic and Copper Age (Fig. 5). The  $\delta^{15}\text{N}$

values for all of the humans analyzed were relatively high (9–12‰), indicating that a significant portion of the protein in their diet came from animal meat and dairy products. However, by fertilizing their crops with livestock manure, the Late Neolithic and Copper Ages populations may have enriched the  $\delta^{15}\text{N}$  values in their bones even if they had a mixed diet based on crops and animal products. While there was no increase in  $\delta^{15}\text{N}$  enrichment from the Late Neolithic to the Copper Age, as originally proposed, the  $\delta^{15}\text{N}$  values were significantly more enriched than Early and Middle Neolithic human samples analyzed in previous studies (Fig. 6). This may indicate that the secondary products of domesticated livestock (dairy and/or manure, as well as meat) were exploited by the Late Neolithic tell communities and the dispersed Copper Age groups. Moreover, the domesticated animals (cattle, pig and sheep/goat) from this study exhibited enriched nitrogen isotopes compared to domesticated animals from earlier time periods, which supports the possibility that  $\delta^{15}\text{N}$  enriched crops were being used for animal fodder, in addition to human consumption.

#### Assessing the intensity of animal use using residue analysis

In order to explore the use of animal products on the Great Hungarian Plain, and dairy products in particular, ceramic sherds were examined for the presence of animal fat residues. The samples were collected from six Neolithic and Copper Age sites: Vésztő-Mágor, Körösladány-Bikeri, Vésztő-Bikeri, Békésszentandrás-Furugy, Doboz-Sarkadi-úti erdő, and Gyula-Remete (shown in Fig. 2). After extracting the residues from each ceramic sherd using methods based on those originally defined by Evershed and colleagues and further described by Copley and colleagues (Copley et al., 2003; Evershed et al., 1997; Hoekman-Sites, 2011, 115–117), each sample was analyzed using gas chromatography-mass spectrometry (GC/MS) to determine if animal fat was present. Out of the 240 archaeological samples tested, 122 contained some type of animal fat residue. The general trend is an increase in animal product use in the Middle and Late Copper Age periods (Fig. 7). Before the Middle Copper Age, the percent of samples with animal fat residue was below 50%. During the Middle and Late Copper Age, the percent of samples with animal fat residues ranges from 66% to 68%. Examining the total percentage of ceramics with animal fat residues allowed us to gauge the general importance of animal products and how that importance changed through time.

Several samples with animal fat were tested further to identify the type of animal fat present. Compound-specific isotopic analysis was used to determine the source for the animal fat based on

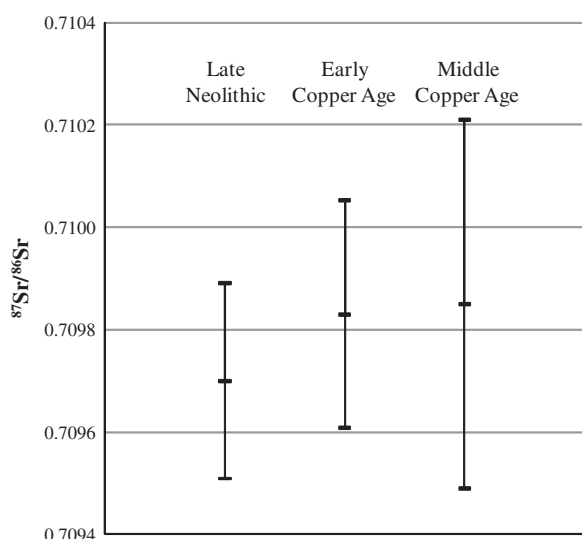


Fig. 3. The mean and standard deviation of  $^{87}\text{Sr}/^{86}\text{Sr}$  values for human tooth samples by time period.

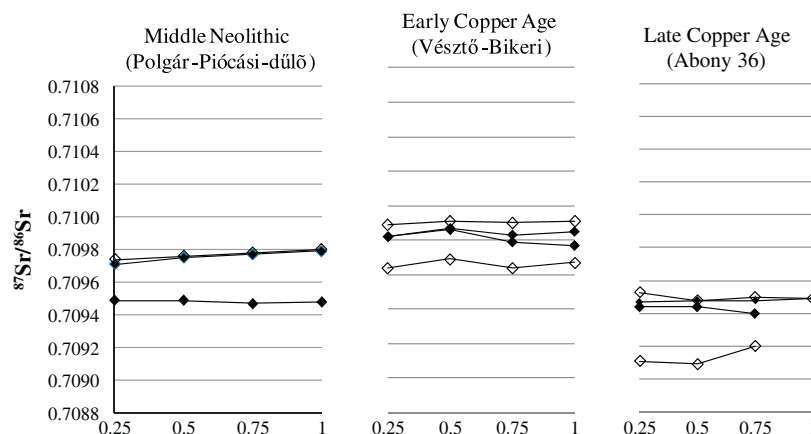
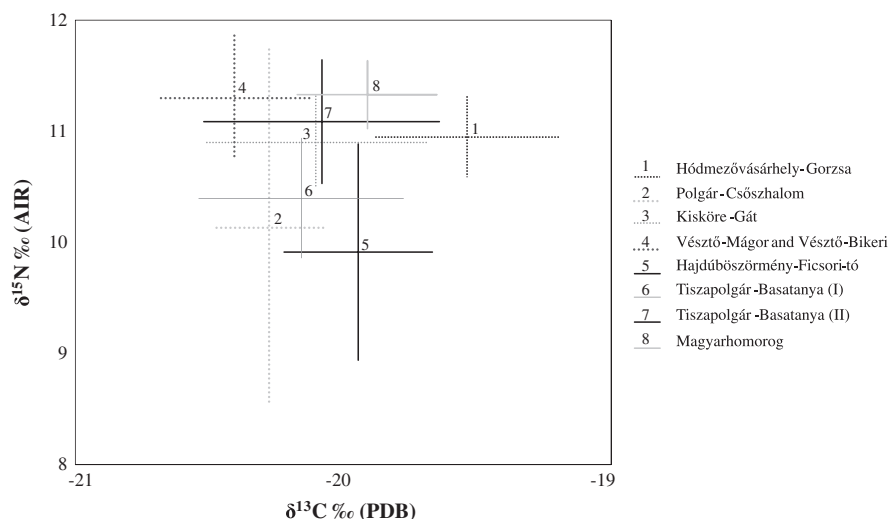
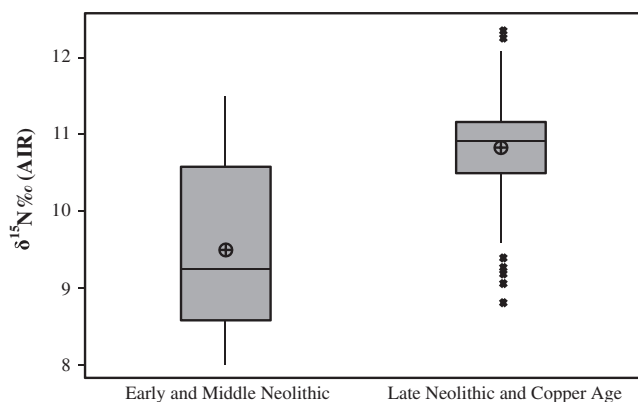


Fig. 4.  $^{87}\text{Sr}/^{86}\text{Sr}$  values from sequential samples of sheep/goat (closed diamonds) and cattle molars (open diamonds) from Polgár-Piócási-dűlő, Vésztő-Bikeri, and Abony 36. X-axis shows the distance samples were taken for each tooth from the neck to the crown in inches.





**Fig. 5.** Stable isotope data for humans from the Great Hungarian Plain by site. All means expressed as  $\pm 1 \sigma$ . The standard deviation is expressed as dashed lines for the Late Neolithic samples and solid lines for the Copper Age samples.

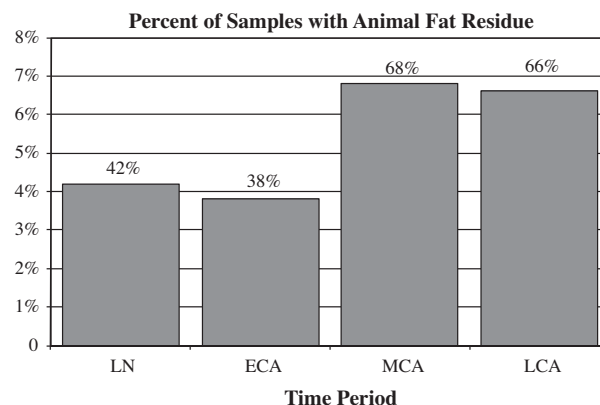


**Fig. 6.** Boxplot showing the difference in  $\delta^{15}\text{N}$  distributions between the Early and Middle Neolithic humans (data from: Whittle et al. (2002) and Reynard and Hedges (2008),  $n = 14$ ) and the Late Neolithic and Copper Age humans (data from this study,  $n = 83$ ). 50% of  $\delta^{15}\text{N}$  values fall within the box; the horizontal line within the box indicates the median value, while the circle represents the mean; the vertical lines represent the range of data, and stars represent possible outliers.

variation in the stable carbon isotope ( $\delta^{13}\text{C}$ ) values. Out of the 40 samples tested, one contained ruminant dairy fat residue, 20 contained ruminant adipose fat, 14 contained porcine adipose fat, and five had sources that could not be determined.

The type of animal fat identified in the 40 samples tested varied significantly through time, although some of the variation is likely due to the small sample size. Figs. 8 and 9 illustrate the source of the animal fat residues, by time period. Ruminant and porcine adipose fat residues were identified in every time period examined. The only sample that could be unambiguously identified as dairy fat residue came from the Early Copper Age. In the Middle Copper Age, the percent of samples with porcine adipose fat residue is higher than at any other time, with more than 50% of the samples tested identified as porcine. These results strongly suggest that while ruminants and pigs were utilized regularly through all time periods studied, the nature of dairy product use on the Great Hungarian Plain was sporadic. Dairying was not a large part of the economic or social system.

Of course, this level of interpretation is still relatively simplistic, since vessels may have had multiple functions. Here we can distinguish a general use signature for each vessel, thus identifying



**Fig. 7.** GC/MS results summary, showing the percent of samples that contained animal fat residue for each time period.

which type of residue predominates. While only one sample could be unambiguously identified as dairy fat residue, other vessels may have contained small amounts of dairy products along with other products (e.g. porcine meat). The use of one vessel for several tasks seems less likely for these vessels than modern ones because of their permeable nature, however. The unglazed vessel interiors, which allowed for residues to enter and adhere easily, also made it difficult to fully remove the original contents. Vessels used to cook meat would always have a thin layer of meat fat on their interior surface. The functionality of this residue was recognized by people as early as the Neolithic (e.g. Joffe, 1998).

## Discussion

### Population mobility

It was proposed that human strontium isotope ratios would be more variable during the Copper Age if their primary food source, livestock, was being grazed over larger, and hence isotopically more variable, environments. The livestock of these communities were also tested to evaluate whether cattle, sheep and goat tooth enamel recorded more variability or seasonal movement between highland and lowland pasture. The strontium data from both

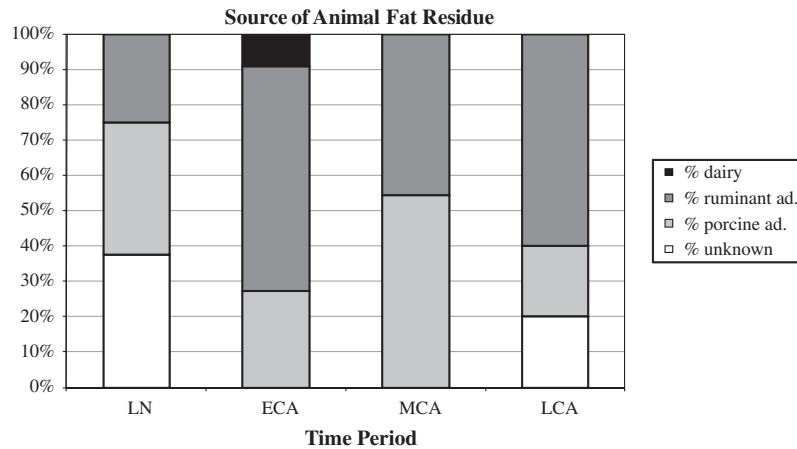


Fig. 8. Source of animal fat residues by time period.

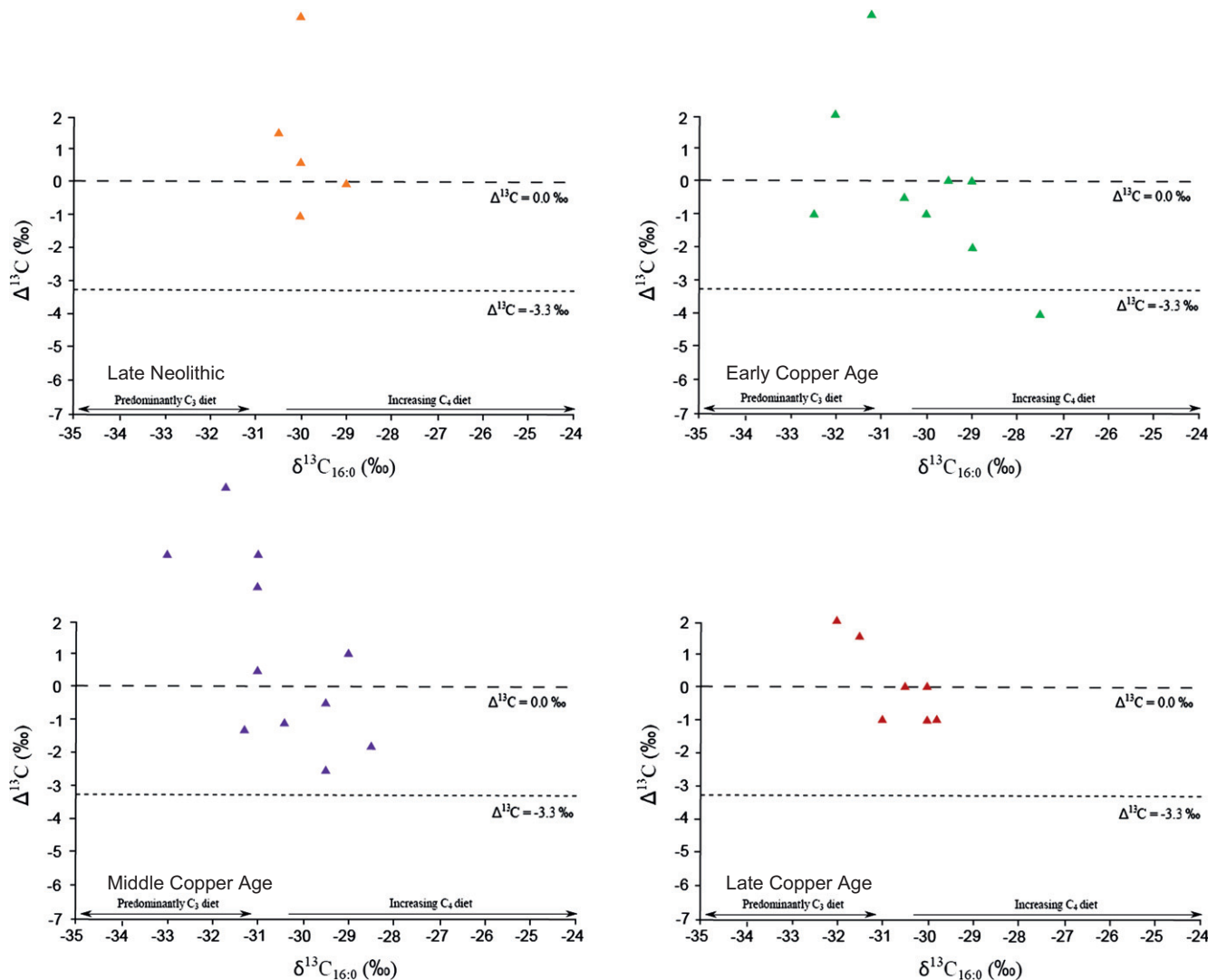


Fig. 9.  $\Delta^{13}C$  values (defined as  $\delta^{13}C^{17}-\delta^{13}C^{15}$ ) plotted against  $\delta^{13}C^{15}$  values by time period. The dotted lines in these graphs are interpreted as follows: values that fall below the  $\Delta^{13}C = -3.3$  ‰ line are interpreted as dairy fat, values that fall between  $\Delta^{13}C = -3.3$  ‰ and  $\Delta^{13}C = 0.0$  ‰ are interpreted as ruminant adipose fat, and values that fall above  $\Delta^{13}C = 0.0$  ‰ are interpreted as porcine adipose fat.

human and animal teeth presented above all exhibit the relatively high isotope values of the Plain's soils and water systems. There is

no significant increase in variability from the Late Neolithic to the Early Copper Age, which indicates that the size and diversity of



grazing land for domesticates did not increase when other aspects of culture (settlement patterns, ceramic style, trade patterns and mortuary customs) were changing. There is also no evidence that herds were being grazed in the uplands where lower strontium isotope values exist.

The carbon and nitrogen data also do not exhibit any changes between the Neolithic and Copper Age indicating that while domesticates became more important in the faunal assemblages, animal protein consumption remained relatively constant. The carbon and nitrogen data, in conjunction with the strontium results for domesticated livestock, both provide evidence that economic mobility – i.e., daily, seasonal or residential movement of people and animals associated with an agropastoral or pastoral system – is highly unlikely for the Late Neolithic and the Copper Age. And certainly a shift towards a more pastoral economy can no longer be used to explain the changes that occurred during the Late Neolithic – Early Copper Age transition. This conclusion is corroborated by recent work by Gyucha et al. (2011) on paleoenvironmental reconstruction and settlement dynamics in the Körös Basin, where they found that regions ideal for large animal herds, like the dry and grassy areas of the Maros fan, were not occupied until the Late Bronze Age and Iron Ages when large-scale animal husbandry and extensive grazing was being practiced.

There did turn out to be an increase in human strontium isotope variability during the Middle Copper Age, when there is also an increase in animal fats found in the ceramic assemblages. While it does not appear that this variability is due to increased herd mobility, it may signify that people were interacting within a broader social network of the Great Hungarian Plain and perhaps animals played a role in the exchange of people, ideas and products.

#### *Secondary products*

While traction, dairying, manuring, and wool-production do not appear to have developed out of one core idea (as discussed earlier), they are related by the fact that they are all means of intensifying production. Bogucki (1984b) and other researchers have suggested that the cultural shift that occurred at the beginning of the Copper Age was the result of an intensification of animal product use, including an increase in dairying. In order to test this hypothesis, 240 ceramic sherds from the Late Neolithic and Copper Age were tested to assess the evidence for dairying intensification as well as to examine general patterns of animal use. The results presented above describe changes in both primary and secondary animal products.

While we know from previous research that agricultural intensification occurred from the Middle to the Late Neolithic periods and was followed by a period of abatement from the Late Neolithic to the Early Copper Age (Kalicz, 1970; Makkay, 1982; Parkinson, 1999, 109; Raczyk, 1989; Yerkes et al., 2009), the residue analysis results show that dairying played a minor role in this pattern. Only one dairy residue sample was clearly identified out of the 40 tested from the Late Neolithic and Copper Age (2.5% of samples tested to identify the type of animal fat present contained dairy fat residues). Despite this, other animal products were major contributors to the early village economies on the Great Hungarian Plain. Animal product use was widespread, as indicated by the percent of samples containing animal fat residues (51% of samples tested to identify if animal fat was present contained animal fat residues). A review of the faunal data (Tables 1 and 2) indicates that the majority of animal products used came from domesticated species. Changes in animal product use were examined through time to determine their impact on observed periods of intensification (see Fig. 7). During the period of abatement from the Late Neolithic to the Early Copper Age when human settlement patterns were dispersed over the landscape, there was a decrease in the general

level of animal product use. The percent of porcine adipose fat residue declined, while the percent of cattle adipose fat residue increased (see Fig. 8). (Unfortunately, the relatively high percent of residue samples from the Late Neolithic that could not be identified decreases the significance of these results.) From the Early to the Middle Copper Age, there was a significant increase in animal product use, which indicates a period of strong intensification. During this period of increase, the percent of animal fat residues identified as cattle adipose decreased, while the percent of porcine adipose fat residues increased.

#### *Other aspects of animal husbandry: foddering and manuring*

So far we have focused on the interrelated issues of herd mobility, animal consumption and animal production, but our data sets also provide potential insight into other aspects of animal husbandry. For example, foddering choices, while not directly related to the consumption of animal products, are another aspect of agricultural and economic choices. Fig. 9 can also be used to learn about foddering sources of domesticated animals consumed. Animals who consume a predominantly  $C_3$  plant diet have  $\delta^{13}C_{16:0}$  values ranging from  $-36$  to  $-31$ . As more  $C_4$  food sources are introduced into their fodder, the  $\delta^{13}C_{16:0}$  values for the animals shift to higher (i.e., less depleted) values. All Neolithic samples fall into a relatively narrow range of  $\delta^{13}C_{16:0}$  foddering values ( $-30.5$  to  $-29$ ). Samples from the Copper Age periods have a wider range of  $\delta^{13}C_{16:0}$  foddering values: from  $-32.5$  to  $-27.5$ . The range is most broad in the Early Copper Age and remains broad through the Middle Copper Age, signalling greater variability in foddering sources and a larger contribution of  $C_4$  plants in the diet of some domesticates. Significantly, in the Late Copper Age, the range of  $\delta^{13}C_{16:0}$  values narrows considerably and may represent a more directed foddering strategy.

Similarly, the elevated nitrogen isotope values found in human bone collagen from this study (mean:  $10.8\text{‰}$ ) may reflect the practice of using the animal byproduct manure to fertilize gardens and fields around Neolithic and Copper Age settlements. Relatively high  $\delta^{15}N$  values have been found at other Neolithic and Copper Age sites in Europe (e.g., Dürrwächter et al., 2006; Honch et al., 2006; Richards et al., 2003) and are generally interpreted as evidence of diets based primarily on animal proteins (meat and dairy). However, experimental studies that have tested the effects of manure fertilizer on modern cereal crops indicate that manuring leads to enriched  $\delta^{15}N$  values, sometimes several per mil higher than the assumed value of  $3\text{‰}$  used in most paleodietary reconstructions (Bogaard et al., 2007, 340; Fraser et al., 2011). If manure fertilized crops contributed to the diet of Neolithic and Copper Age populations, then a mixed diet of terrestrial animal and plant protein would have a higher  $\delta^{15}N$  range than previously predicted (e.g.,  $9\text{--}11\text{‰}$ ).

While evidence for manuring in Eastern Hungary needs to be tested with future research, there is a growing literature in support of the “manuring effect” in the development of early farming societies in southeastern Europe (Bogaard, 2004; Bogaard et al., 2007; Fraser et al., 2011). Traditionally the use of manure for both fertilization and fuel is seen as a relatively late development that occurred later than the use of other secondary products (Bakels, 1997). In Greece, the only part of southeastern Europe that has been tested extensively for manuring, the earliest evidence for manuring dates to the Bronze Age (Bintliff, 2005; Valamoti, 2004; Valamoti and Jones, 2003). Bogaard (2004) suggested that manuring was practiced in Europe from the start of the Neolithic based on an archaeobotanical study of weed assemblages. She further stated, “it was precisely such integration of plant and animal (by-) products (such as manure) that enabled farming to successfully spread across a range of environments” (Bogaard et al.,

2007, 336). In light of the other evidence from this paper (local humans and animals, low dairy use), the high nitrogen values in humans throughout the Late Neolithic and Copper Age may indicate that manure fertilizer played an important role in agricultural production.

#### *Plant cultivation*

Our discussion of animal husbandry must also consider plant cultivation, as the two were most likely practiced together in a small-scale but intensive system close to settlements. Detailed archaeobotanical studies are lacking for Late Neolithic and Copper Age sites in the region. Still, we know that cultivation was practiced to some extent, as signalled by seeds of common domesticates at Neolithic and Copper Age sites (e.g. Kasper, 2003). Further, we can limit the type of cultivation practiced based on the lack of mobility described above. The strontium isotope data indicates that life during the Late Neolithic and Copper Age was very local, and that individuals often lived their whole lives close to the place where they grew up. This data fits with the “garden plot” model proposed by Jones (2005), where settlement mobility is limited by the intensive work required during the cultivation season as well as the soil enrichment benefit of repeatedly using the same location. While limited mobility can also be seen as an indicator of long-term field farming (i.e., large fields of monocropped grains/pulses), this view is coloured by our observations of modern farming and probably has little connection with the earliest farming communities in southeast Europe.

While the small-scale clearance of land for cultivation in Neolithic Europe precludes large-scale monocropping, early cultivation may have instead more closely resembled biodynamic or organic farming practices which can be observed today. The value of the biodynamic model for archaeologists is the focus on ecological diversity. Animal use must be studied as part of a food-collection system that also involves plant cultivation, water management, and other related issues instead of a separate practice taking place in a cultural vacuum. Along with Jones, Bogaard (2005) also supported a model of intensive mixed farming, where cultivation was labour-intensive and domesticated animals played a crucial role. She asserted that in Europe, there was a high level of interdependence between plants and animals in early farming communities that allowed for a high level of household autonomy. This view of early farming, supported by multiple studies (e.g. Bogaard, 2004; Halstead and Jones, 1999; Jones, 2005), fits our data as well (i.e. evidence of plant cultivation and domesticated animal use coupled with a lack of population mobility).

#### *Subsistence strategy and culture change*

The gradual abandonment of large tell sites in Eastern Hungary, in favour of smaller and more dispersed settlements is a trend that has been observed throughout southeastern Europe during the Late Neolithic and post-Neolithic (Chapman, 1990; Sherratt, 1984; Tringham and Krstić, 1990; Tringham et al., 1992). If changes in animal husbandry practices do not help explain this dispersal pattern, then what factors might have played a role in cultural change during the Late Neolithic and Copper Age? Several researchers have proposed that the household, or nuclear village, is more economically advantageous than larger social groups within a delayed-return, seasonal farming economy as described above (e.g., Bogucki, 1993; Flannery, 2002; Halstead, 1999).

In larger villages where risk is assumed at the group level and agricultural produce is shared, there is little incentive to intensify (Flannery, 2002, 421). Conversely, in smaller groups where risk is assumed at the family level, storage is private and there is more incentive to intensify production because surplus can be stored

(and consequently not shared with a wider group). Flannery (2002, 421) hypothesized that the shift from larger to smaller groups in the PPNB of the Near East occurred because Neolithic villages became so large that families did not consider themselves closely enough related to continue to share the risks and rewards of production. Halstead (1999) proposed a similar model for the gradual isolation of the household as the primary unit of social and economic production in Neolithic Greece. He postulated that while this smaller unit resolved contradictions between the ideology of sharing and a delayed-return economy, it also necessitated a reorganization in the social mechanisms for interaction and integration (Halstead, 1999, 90–91). Despite the production advantages, the household is not stable on its own and needs to be tied into a larger social network to mitigate the risks of labour shortages and agricultural failure. According to this model, marriage alliances, visiting relationships and exchange partnerships would have provided a crucial social risk management system that was established and maintained during goods years (through hospitality, labour services, and the fattening of livestock) and called upon during bad years (Halstead, 1999, 89).

Recently, collaborators of the Körös Regional Archaeological Project (KRAP) proposed a related socioeconomic model for a gradual transformation from the Late Neolithic to the Copper Age within the Körös Basin of the Plain (Gyucha et al., 2009; Parkinson et al., 2010). They suggested that while population growth and long-term occupations in the Late Neolithic may have depleted the forests and soils around nucleated settlements, which may have caused internal conflict and competition for resources, opening the forests and spreading manure on the fields may have created a more sustainable agricultural system. This system, based on mixed farming and animal husbandry, could be employed away from the nucleated tell-centred Late Neolithic settlement complexes. Furthermore, there seems to have been a change in social organization that favoured less integration at the household and settlement level and more interaction between settlements over broader geographic areas (Parkinson, 2006; Parkinson et al., 2010; Yerkes et al., 2009). Settlements composed of smaller household units dispersed, perhaps because smaller settlements were more economically viable in the heterogeneous or “patchy” environment of the Körös Basin, especially if they were occupied for shorter periods of time.

As the KRAP directors and many other scholars of this region have observed, smaller sites, and likely smaller units of social and economic production eventually replaced the larger, integrated tell societies of the “Mature” Neolithic throughout much of southeastern Europe. And while this smaller social unit, perhaps the household, may have been more economically viable within a delayed-return farming system and an emerging anthropogenic landscape, it required a more extensive network of regional exchange to mitigate the risks of labour shortage and agricultural failure. On the Great Hungarian Plain, evidence for more variable strontium isotope values in humans, along with regional exchange, homogenization of ceramic styles, and the use of communal cemeteries may hint at new cultural mechanisms that were developing to facilitate interaction, trade, and risk management between these more independent hamlets. Additionally, evidence for increasing animal product use in ceramic sherds during the Middle and Late Copper Age may signify animal production practices in-line with the intensification incentives of smaller, independent economic units.

#### **Conclusions**

In this article, we presented isotopic and residue analyses to identify patterns of subsistence and mobility change on the Great

Hungarian Plain from the Late Neolithic through the Copper Age. Our research focuses on two main questions: (1) did herd mobility increase? and (2) did domesticated animal products increase in importance? Both questions relate directly to the subsistence strategy of the local population. Increased herd mobility and even transhumance has been suggested by previous researchers to explain the shift from nucleated to dispersed settlements which occurred at the start of the Copper Age. In a similar manner, an increased reliance on domesticated animals has been used to explain the settlement shift, due to the increase of land needed to support larger herds. These previous theories directly link observed culture change (i.e. major changes in settlement patterns) to shifting subsistence strategies.

We addressed these questions by synthesizing complementary lines of evidence to examine subsistence and animal management strategies from several angles. Evidence for changes in mobility came from an examination of strontium isotopes, which showed no large shifts in herding practices at the start of the Copper Age. This negates the theory that the settlement dispersal observed was due to increased herd mobility. The lack of seasonal variability in strontium isotope levels in animal bones illustrates that herds did not participate in lowland/highland transhumance. Herd movement did not increase in the Copper Age, so we must look elsewhere to explain large cultural changes observed. There was a statistically significant increase in strontium isotope levels in humans during the Middle Copper Age, which might indicate an increase in human interaction and movement within the confines of the Plain.

The role of domesticated animal products was investigated by examining carbon and nitrogen isotopes, as well as through residue analysis. The carbon isotopes showed no clear change through time, and further indicated a diet of terrestrial plants and animals with no significant contributions from freshwater fish or C<sub>4</sub> plants like millet. While nitrogen isotopic values remained relatively constant from the Late Neolithic through the Copper Age, they were significantly enriched compared to earlier research on Early and Middle Neolithic samples (Giblin, 2011). These enriched nitrogen isotopic values, which were present in all human and animal bone samples tested, indicated that animal protein was an important component in the diet from the Late Neolithic on. Aside from consuming more animal protein, another possible cause for enriched nitrogen isotopic levels could be an increase in manuring, which increases the nitrogen level in soils used to grow food (Bogaard et al., 2007). Residue analysis results showed that more animal fats were present in pottery from the Middle and Late Copper Age, indicating an increase in the level of animal product use in the Middle Copper Age. While we generally assume that this increase is due to more animal products in the diet, some may be related to the production of other items that use animal products (like sealants, paints, medicines, or hygiene items).

The evidence summarized above demonstrates that an increased reliance on domesticated animals does not fully explain the shifts in cultural behaviours observed at the start of the Copper Age on the Great Hungarian Plain. At the time when settlement patterns, burial practices, etc. were altered, the data do not support similar drastic shifts in animal management practices. What the data do indicate is some sort of subsistence shift during the Middle Copper Age. The residue analysis results show an increase in the use of animal products at that time. Also, more variable strontium isotope values during the Middle Copper Age imply an increase in the range of human movement and resource acquirement within the Plain, although this variability does not appear to be related to animal herding. While much has been written about the Neolithic/Copper Age transition, not as much attention has been focused on cultural shifts during the Middle Copper Age. Currently, the Middle Copper Age is seen as a continuation of the Early Copper

Age, a flourishing of the Tiszapolgár culture. This appears to be a key period to investigate in further research.

Here we have shown how several types of research can be used together to synthesize a more complete picture of the role of domesticated animals in Late Neolithic and Copper Age societies on the Great Hungarian Plain. In the future, archaeobotanical material should be studied along with the fauna, in a collaborative effort to more fully understand the shifting patterns of domesticate use.

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